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BIOLOGICAL AND HOST FACTORS IN RELATION TO IPS OUTBREAKS IN THE SOUTHERN SIERRA SUB-REGION

Progress Report - Season of 1947

By

George R. Struble

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BIOLOGICAL AND HOST FACTORS IN RELATION TO IPS OUTBREAKS IN THE SOUTHERN SIERRA SUB-REGION

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George H. Struble

INTRODUCTION

An investigation of the factors involved in recent outbreaks of Ips confusus Lec. in ponderosa pine stands in the southern Sierra sub-region was begun in 1945. Preliminary data on the association of logging slash with subsequent outbreaks in reserve stands remained in agreement with previously published information[2] that such outbreaks were associated with sporadic cuttings and not with continuous logging operations where there was a constant supply of slash to serve as a breeding medium.

Studies continued in 1946[3] revealed many inconsistencies in the behavior of Ips which could not be explained fully on the basis of known information. Outbreaks in reserve stands in the face of an apparently continuous fresh slash supply indicated that perhaps other factors were important, and that their full significance could not be determined in a shorter period than several years, during which fluctuations in populations and aggressiveness were likely to occur. The factors indicated to be of greatest importance were: (1) Seasonal changes in the feeding and breeding habits; (2) fluctuations in natural insect enemies and prevalence of fungi; and (3) changes in the host environment, particularly phloem moisture. These factors were first to be considered in the 1947 field investigation. Included, also, were studies on certain practical phases of control through slash alterations to discourage breeding.

Basic material for these studies was obtained from the same general areas as in 1946 - in western Madera and Mariposa counties within close

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1/ This progress report is presented as a summary of 1947 data. It serves as a reference to further investigative work continued on this problem in the same areas during 1948. Grateful acknowledgment is given to the helpful assistance of E. T. Engen, Field Aide, in securing basic data.

2/ Division of Forest Insect Investigations, 1927. The Relation of Insects to Slash Disposal. U.S.D.A. Circular 411, Washington, D. C.

3/ Struble, G. R., 1947. A Study of Factors in the Development of Ips Outbreaks. Progress Report of Sierra Studies, 1946.

proximity of Miami Field Base. An unusually open spring and long, dry fall proved advantageous to steady logging activity from mid-March through November for the 30-odd sawmills in this vicinity, with subsequent early and continuous heavy breeding in the slash by Ips confusus; this resulted in the pyramiding of populations by midsummer. An improvement in rearing facilities through the adoption of a new type emergence cage provided a much stronger basis for reliable information on populations than obtained previously.

MATERIALS AND PROCEDURE

Much of the information on seasonal biology was obtained from records established on designated slash or infested trees. These sources were checked periodically during the course of a given generation throughout the different seasons. Emergence data from representative samples of infested slash and standing trees were secured through the use of specially designed cages (figure 1), each accommodating infested short log sections having three square feet of bark area. The emergence data were supplemented when necessary by counts of mature brood from infested log sections, each having three square feet of bark area, an adopted standard sample size.

Most of the information on insect predators and parasites was obtained through emergence and collection of the different species occurring in infested log sections placed in emergence cages. Daily emergence records by species were kept in the same manner as those for Ips throughout the Ips emergence periods. Specimens were placed in alcohol for later identification. The number of any given species of parasite or predator compared to the number of emerging Ips adults was used as a basis for determining effectiveness as a control factor.

Some preliminary studies of the possible effects of overcrowding by both the parent adults and subsequent Ips progeny on the ultimate production of mature broods were undertaken through one controlled rearing experiment. Information on the effect of fungi, particularly blue-green (Penicillium) fungus, on the success of mature brood development was obtained in a general way through observations on the association of brood failure with abundant fungus growth.

Studies on phloem moisture in relation to developing Ips progeny were undertaken through field tests. Measurements were made each ten days through the Ips development period. This was done by securing 20 gram wet-weight sample strips of phloem peeled from the logs after the corky bark had been chipped away. The samples were dried in an oven at 200°F. until thoroughly dry, then were reweighed to determine the loss of moisture. All moisture measurements were expressed as percentage of dry weight.

Practical considerations in the control of Ips outbreaks were given in studies to determine: (1) Whether the amount of mature brood development was influenced by the age of host trees felled in logging operations; and (2) the effectiveness of top lopping as a means of limiting the amount of breeding and subsequent attacks in the reserve stands.

SEASONAL BIOLOGY AND HABITS

Overwintering Habits

Field data taken from infested slash and standing trees during the winter and spring of 1947 and 1948 showed that the winter period was spent beneath the bark in advanced stages of development, (predominantly adults and a limited number of brood as advanced larvae and pupae). Attacks made in slash during the latter part of July, 1947, produced mature adults, approximately 75 percent of which emerged during October, and 25 percent of which remained in the slash material to spend the winter beneath the bark. Attacks in slash during the latter part of August, 1947, produced, by late October, callow and brown adults that remained beneath the bark all winter. These turned gradually to mature black adults ready for emergence in the spring of 1948. Later attacks during the fall of 1947 produced broods in advanced stages of development by the onset of colder weather, and these continued to develop to maturity gradually during the winter months. New attacks in living trees in the fall of 1946 and 1947 were apparently ended both years by the first of November; it was found that the broods produced here likewise had completed development to maturity by the onset of winter and hibernated as adults beneath the bark. Many adults attacking late in the season of 1946 did not establish broods, but remained beneath the bark, apparently for food and shelter; and although the trees in which these adults overwintered were killed, no broods were produced. These adults emerged in the spring, presumably to establish broods elsewhere. There was no apparent deviation from this condition in the fall of 1947 and subsequent winter and spring of 1948. No very young stages (eggs or small larvae) were found in either year during the late fall and winter.

Generations produced

During 1946 the detailed record on seasonal biology revealed that four generations of Ips confusus were produced in the Miami area; this was considered to be about normal, assuming that the first spring attacks are started about April 15th. Again, in 1947, there were four generations, even though active attacks were made unusually early in the spring. The first attacks in slash occurred somewhat prior to March 15th. An average of 11 samples representing the different generation periods (table 1) provides ample evidence of generations scheduled as follows:

Generation	Period of Development: Dates (Attacks to Peak Emergence)	Days
I	3/15/47 to 5/25/47	70
II	5/20/47 to 7/15/47	55
III	7/5/47 to 8/20/47	45
IV	8/20/47 to over-winter	

These records, as presented in detail by table 1, show the variation in time from attacks to complete emergence of separate broods throughout the 1947 season, and indicate also the great degree of brood overlapping which takes place.

Table 1.--Development Periods of Separate Ips Broods in 1947

Name of Sample	Attacks	Events and Dates: Emergence: First	Peak	End	Number of Days (Emergence): First	Peak	End
Bradshaw	3/15	5/15	5/25	6/15	60	70	90
Mariposa G. S.	4/20	6/20	7/10	7/27	60	80	98
Oliver Creek	4/25	6/11	6/20	7/23	52	61	95
Chewchilla Creek	5/ 7	6/20	7/ 7	8/ 1	43	61	87
Harris Ranch	6/10	7/ 9	7/29	8/18	29	49	69
Ferguson Ranch	6/15	7/18	7/30	8/12	33	45	58
Goodwin	6/25	7/29	8/31	9/16	34	67	84
Barrett Ranch	6/25	7/29	8/ 7	9/ 2	34	43	69
Ferguson Ranch	7/ 1	8/18	9/ 4	9/22	49	66	85
Hugh Ryan 1A	8/ 4	9/ 9	10/ 4	ov*	36	61	ov*
Hugh Ryan 1J	8/ 1	9/11	9/26	ov**	41	56	ov**

* 10 to 20 percent of adults remained under bark to overwinter
** 5 to 10 percent of adults remained under bark to overwinter

Abundance of Mature Broods

1. Emergence data, 1947.

In the tabulation below is shown the average emergence of adults from samples grouped according to season, principally from slash--(four samples from standing trees).

Table 2.--Emergence of Ips Confusus in 1947

Breeding Source	No. of Samples	Bark Area, Sq. Ft.	Collected: Total	Emergence, *: Average Sq. Ft.
Overwintered slash attacked in spring	2	6	164	27
Spring slash attacked in April and May	5	15	2,428	162
Summer slash attacked - In June and July	5	15	2,181	145
In July and August	2	6	797	133
Fall slash attacked in August and September	2	6	857	143
Standing trees	4	12	797	66
Totals	20	60	7,224	120

* Includes only adults which emerged in collection chambers, and not those individuals which remained to die within the cage or within the log, which together with parent adults would include an additional adult population of about 21 percent.

These figures show a consistently high population emerging from fresh slash material during the spring, summer, and fall, with highest average emergence from spring and early summer slash material. As in 1946, the 1947 emergence from overwintered slash material attacked in the spring was nominal, less in fact than the attacking populations, and for this reason is not a factor in the upbuild of Ips populations. The emergence from attacked trees was appreciably less in the limited number of samples than in fresh slash material, but the data are insufficient as yet to conclude that this is consistently the case.

2. Population data, 1945-1947.

In the tabulation which follows, a comparison is made in the amount of mature brood per unit of bark area for three different slash areas during this three-year period. Although the data are limited, there appears to be a significant difference in populations between years and between areas, which may throw some light on the reasons for attacks made in reserve stands. The figures given are average for the limited number of samples taken from each area.

Table 3.--Average Mature Ips Broods Produced, 1945 to 1947

Location	Bark Area (Sq. Ft.)			Average Brood Per Sq. Ft.		
	1945	1946	1947	1945	1946	1947
Jerseydale	8	2	5	118	145	237
Hugh Ryan	9	12	45	87	187	102
Fish Creek	8	0	6	95	95*	95

* Estimated; no counts were made in 1946

The most significant figures are those for the Jerseydale area; they indicate a tendency toward increasing populations for the three-year period. They appear all the more significant in view of the sporadic killings which occurred in this area beginning in 1946 and continuing with greatly increased virulence in 1947. However, the number of samples is too few to warrant more than an indication of a possible trend in increased populations and their subsequent effect.

At Hugh Ryan there was a definite population increase in 1946 over 1945, which is in line with what happened at Jerseydale; but no subsequent killing in the reserve stand occurred either year. The decline in populations in 1947 over 1946 was probably due to a change in logging schedule which in 1947 did not start until July 1, when in 1946 it was started in April. However, a small amount of subsequent killing in reserve timber occurred early in September, 1947, despite these population differences. This kill, however, had no apparent connection with breeding in the area, since the attacks occurred well in advance of the emergence of broods reared in the slash material there. The source of these attacks can be attributed only to an

influx of beetles attracted from the outside by the fresh slash material in the area.

In the Fish Creek logging areas, the same level of populations was indicated for each of the three years. This result may be expected in the higher elevations, especially in mixed ponderosa pine - sugar pine type. No aggressive killing occurred in this area in any of the three years.

Adult Attack on Saplings

A few observations were made on this habit of attacking groups of large and small saplings. During the first week in August several of such groups were found, the largest of which was estimated to contain over 500 trees. (figure 3). Examinations made at that time revealed only a few of the adults remaining under the bark near the basal portions of the stem, most of them having abandoned these trees. There was very little evidence of any broods having been produced; but, instead, the inner bark and sapwood surfaces contained a pattern of numerous adult feeding channels. The fading of these trees at the time of examination indicated that the invasion by adults had been made less than a month earlier. However, the hordes of beetles attacking these trees, as evidenced by the complete destruction of inner bark tissues, remained only until the food supply was gone; then they emerged, presumably to attack elsewhere.

The reason for these concentrated attacks on small trees is not readily understood. It is quite certain that it is not a feeding habit for sexual maturity, for repeated controlled rearings have demonstrated that normal broods result from the attacks of newly emerged adults. Neither does it appear to be a feeding habit induced by a dwindling supply of fresh slash material, since such attacks have been found in sapling groups surrounded by fresh slash on the ground. The more valid reason for these attacks appears to be a response to an attraction influence on the part of the sapling groups. Since these attacks have been found to occur after midsummer, it is plausible to assume that the attractive influence was induced by competition for soil moisture. The fact that all of the groups killed in 1947 were located on or near the crests of ridges supports this theory.

The same factor appears to be in play in the case of attacks on larger trees, for the first invasions made in midsummer occurred during 1946 and 1947 on or near the crests of ridges, with later invasions in trees down the sides of ridges and into the flats. The only difference between attacks in reproduction and in standing trees appears to be a matter of relative weakness, induced possibly by moisture deficiencies, which may be first manifested in the smaller trees growing in close competition with each other.

Parent Adult Emergence

The emergence of parent adults from attacked slash or trees appeared to vary considerably as to the number and period. In the case of attacks on saplings, the entire attacking population emerged within about three weeks following the exhaustion of food supply or satisfactory rearing quarters.

Under controlled rearing conditions, the amount of parent adult emergence appeared to be associated with overcrowding, as shown by the tabulation below. In this test, three logs of the same character (adjoining sections from the same tree), each containing three square feet of bark area were used. Variations were made in the number of adults admitted to attack the logs. Where a sub-normal attack was made involving 15 adults per square foot of bark area, only 20 percent of the adults emerged. In the normal and over-crowded logs, the emergence of parent adults was greater than 50 percent. In each case emergence was started 20 days after the initial attacks, indicating that it may have been stimulated by a dwindling food supply.

It is to be noted that the emergence in log #3 was less than in log #2 even though three times the number of beetles were introduced to attack it. Inasmuch as this test was not replicated, no fully satisfactory explanation for the difference is possible. It is probable, however, that many of the beetles used to infest the log were not perfect, since they had been held in dormancy under refrigeration until used. Under these conditions of close confinement there was a noted tendency for the adults to bite off one another's tarsi, even though they were quite inactive. This test does, however, serve to indicate quite definitely that overcrowding influences the amount of parent adult emergence.

Table 4--Amount of Parent Adult Emergence from Attacks on Log Sections.

Log #	Number of Adults Admitted	Number of Adults Emerged	Percent Emergence	Number of Days to First Emergence	Days Total Period
1	45	9	20	21	12
2	135	80	59	19	24
3	405	211	52	19	18

BIOLOGICAL CONTROL FACTORS

Insect Enemies

Again in 1947, insect predators and parasites were found to have no appreciable effect in reducing populations, regardless of the number occurring per unit of bark area. As shown by Table 1, the number of emerging Ips adults in slash material amounted to an average of 146 per square foot, even

though in this same material there was an abundance of different species of natural enemies. The species of predators and parasites are listed systematically in table 5, showing the total number collected and occurrence in all of the reared material from 16 rearing cages.

Table 5.--Insect Enemies Reared from Logs Infested by Ips

Order	Family	Genus and Species	Total Collected	Percent Occurrence
		Parasites		
Hymenoptera	Braconidae	Coeloides brunneri	1	6.2
	Pteromalidae	Pachyneuron aeneiventris	147	68.7
		Coelocybe burkei	2	12.5
	Eurytomidae	Eurytoma sp.	141	68.7
		Predators		
Coleoptera	Cleridae	Thanasimus lecontei	5	18.7
	Colydiidae	Aulonium longum	45	81.2
		Lasconotus lequeatus	63	62.5
	Staphylinidae	Phloeonomus sp.	3	12.5
	Ostomatidae	Species unidentified	1	6.2
	Histeridae	Platysoma punctigerum	3	18.7
		Plegaderus nitidus	1	6.2
Diptera	Dolichopodidae	Medetera aldrichi	42	31.2
	Lonchaeidae	Lonchaea sp.	9	31.2
Hemiptera	Anthocoridae		7	25.0

Among the parasites, two species, Pachyneuron aeneiventris and Eurytoma sp., were about equal in number as well as in distribution in different slash material. The two other species reared were rare.

Colydiids far outnumbered any of the predators found, with Aulonium longum the most evenly distributed. Clerid predators, considered one of the most promising of the coleopterous predators, were few in number and occurrence during 1947, as in 1946.

Effect of Overcrowding on Development of Progeny

Only one experiment was conducted to test the effect of overcrowding, but the results appeared to be of some significance. The test was conducted under the conditions of caging control. This was done by caging separately three freshly cut logs of similar character, each containing three square feet of bark area. In log #1 were established 45 Ips confusus adults, a subnormal attacking number; in log #2 were established 135 adults, a normal attacking number; in log #3 were established 405 adults, or three times the normal attacking number. Attacks were established readily when the test was started. The test was begun July second and completed through emergence of progeny on October first. The significant points of this test are tabulated as follows.

Table 6.--Number of Progeny Produced in Normally Attacked and Overcrowded Logs

Log #	No. Adults Attacking	Number of Progeny - Adults		
		Total	Per Inch - Egg Gallery	Ratio
1	45	297	2.23	6.60
2	135	433	1.73	3.20
3	405	396	1.32	0.98

This test showed that as the attacking population increased, the proportionate number of progeny decreased, as well as the number of progeny per unit of egg gallery constructed. This situation was manifested in 1946 under field conditions in which attacking adults numbering 173 per square foot of bark area were found, together with progeny advanced to callow adults numbering 329-- a ratio of 1.90.

At least part of the proportional difference between parent adults and progeny is compensated for by parent adult emergence and re-attack to establish a second brood. In a test to determine how much of a brood would be established, 135 emerged parent adults were collected and a green log having three square feet of bark area was admitted to attack. The log was attacked readily and a mature brood had developed within five weeks, between July 25th and September second. A count of this brood, predominantly in the adult stage, by the latter date revealed a total number of 348, or 116 per square foot of bark area--a ratio between attacking adults and progeny of 2.58. The test indicates that even though the attacking population may be unusually heavy, with a tendency toward lessening progeny because of the competition for food, the loss may be compensated for by later re-emergence of adults to establish a new attack and second brood elsewhere.

Effect of Fungi

Thus far, the data on fungi or other plant organisms are very limited, but in every case noted, Ips broods have been seriously affected. The incidence of fungi appeared to be on the increase in 1947 over 1946, but there is no assurance that this was actually the case. Among the emergence records and brood count data, there were five cases involving 15 square feet of bark area, which showed quite clearly the effect of fungi (probably Penicillium sp.) on developing broods. Three of the cases, which consisted of short length logs cut from naturally infested tops during midsummer, resulted in an average emergence of 30 adults per square foot of bark area, even though the attack number and length of egg galleries were normal. The other cases consisted of actual counts of mature brood in normally attacked

logs where the average number amounted to 22 per square foot. In the latter cases, the phloem and cambium areas were very moist and slimy. The logs placed in emergence cages were not excessively moist, but the phloem was overgrown with a heavy blue-green fungus. These five cases represent approximately ten percent of the total number recorded in 1947.

The occurrence of fungus growth in the egg galleries and phloem areas appears to be related to the condition of the phloem, which will promote the growth of fungi. This was indicated by one controlled rearing experiment in which the attacking adults were contaminated with fungus spores by placing them in moldy phloem before forcing them to attack a green log. The resultant mature brood amounted to 179 per square foot of bark area, and there was only a very light fungus contamination in the phloem.

INFLUENCE OF PHLOEM MOISTURE

Field tests in 1947 were designed to determine the effect on Ips broods of phloem moisture found in lopped tops as compared with the lessening amount of phloem moisture found in unlopped tops, due to transpiration by the green foliage. The first tests included fresh tops which were created during a logging operation in which nine pairs (18 tops) were selected. The second series of tests included comparisons from trees that were felled and prepared especially for the study. These trees were in different site locations varying as to soil moisture conditions believed to be influential in regulating tree moisture. In all cases, phloem moisture samples were taken each ten days, when a record of Ips attack and brood development also was taken. The phloem samples were peeled from the main stems and sealed in jars until weighed. Moisture determinations were based on the dry weight of 20 gram wet-weight samples. Drying was done in an oven at 200°F.

1. Results of tests with logging slash.

These tests were not fully satisfactory because all except three pairs of tops selected for study were ruined or lost due to logging activity, even though the tops were well marked. Hence, on the basis of the limited amount of data obtained, no conclusions are possible. However, as shown by table 7, the data indicate a significant difference in phloem moisture between unlopped tops and lopped tops, and also in the broods produced. The average moisture of lopped tops increased significantly toward the end of the period of this test, while in unlopped tops it decreased. The resultant broods averaged 50 percent less in the lopped tops than in the unlopped tops.

It should be pointed out that the phloem moisture of individual trees was extremely variable and such influences as it may have had on production of broods is debatable. This result might have been expected from the small number of samples and the variety of exposures in which they were located in the field. Thus, while such brood production appeared significantly more consistent and heavy in the unlopped tops, factors other than phloem moisture may have been responsible.

Table 7.-- Phloem Moisture and Ips Brood Production in Lopped and Unlopped Tops

Tree #	% Moisture at 10-Day Intervals 1	2	3	4	Ips Attacks	Brood Produced Per Sq. Ft.	Per Inch-Egg Gallery
					Unlopped Tops		
UL-1	100.0	119.7	119.7	104.0	6	87	1.70
UL-3	138.0	194.1	124.7	138.0	7	116	2.04
UL-4	112.7	110.5	104.0	102.0	9	122	1.74
Average	116.9	141.4	116.1	114.6	7	108	1.83
					Lopped Tops		
L-3	170.2	127.2	146.9	238.9	10	46	.73
L-8	135.2	143.9	189.8	181.7	9	32	.48
L-9	122.2	135.2	135.2	233.3	5	87	1.85
Average	142.5	135.4	157.3	217.9	8	55	1.02

2. Prepared field test.

Sites I and II were represented in two locations chosen for study in Hugh Ryan basin. On both sites the stands were predominantly ponderosa pine in mixture with occasional white fir, incense cedar, and sugar pine. Both contained vigorous young trees, with a considerable number ranging in diameter from 14 to 18 inches, a desirable size for study. The Site II stand was located at approximately 4,700 feet in elevation, near a ridge top; and the Site I stand at about 4,300 feet, in the flat of Hugh Ryan basin near Miami Creek.

At each location, ten trees, varying in diameter from 14 to 18 inches dbh, were felled. Trees A to E were left intact with limbs attached; all limbs were lopped from trees F to J. The same procedure was followed in both areas. All trees were felled under shaded situations to assure uniformity of attack and lessen the possibility of variations in temperature and subsequent insect responses due to open exposure to the heat of the sun. To assure insect attacks, infested logs containing mature broods of Ips were distributed among the fallen trees.

Phloem moisture data from sample strips of phloem, each weighing 20 grams (wet weight), were taken at 10-day intervals from the time of felling the trees through the development period of Ips confusus. In all, phloem moisture determinations were made at five different times between July 21st and August 25th.

With the advancement of Ips broods to maturity, the bark was removed from representative sample log sections from test trees, each sample containing three square feet of bark area. However, the broods in several of

the trees, especially the Site I group, were not sufficiently advanced by mid-September to allow an adequate check at a time when the field schedule was changed. Hence, the data secured are not to be relied on as fully satisfactory or as a basis for conclusions on the influence of phloem moisture on brood production. Adequate conclusions on the importance of this factor can be justified only on the basis of further replications of this test.

The results gave a much stronger basis for conclusions than the test with logging slash; but they left much to be desired because of the extreme variability in moisture, and also in the number of Ips reaching maturity without apparent relationship to moisture. The attacks made by Ips adults were uniform in all logs under both site conditions, indicating that the amount of phloem moisture was of no consequence as a limiting factor in attractiveness. The basic data as shown in table 8 do not indicate that a relationship between phloem moisture and brood production exists.

The principal points that seem to be manifested by these data are: (1) That the mature broods produced were significantly greater in number in the Site II unlopped trees than in the Site I unlopped trees; (2) that the differences in brood produced appeared to be influenced by the greater phloem moisture in the Site I trees 20 days after felling; (3) that there was less brood in the lopped than in the unlopped trees of Site II, but little difference was indicated in the Site I trees; (4) that in the lopped trees there was a distinct tendency toward more rapid phloem moisture increases 30 days after felling; (5) that phloem moisture differences were not indicated to affect the extension of egg galleries or the establishment of broods.

PRACTICAL CONSIDERATIONS IN IPS CONTROL

Age of Host

By far the greatest proportion of slash involved as a breeding medium for Ips in logging areas studied in this vicinity came from trees varying between young and intermediate ages. The full crowns and thick phloem in the majority of cases, indicating a high degree of vigor, provided an ideal breeding medium for Ips broods. Most of these logging areas, located in the lower elevation ponderosa pine belt, actually contained a high percentage of second growth pines between 75 and 150 years old.

The question as to whether slash from older trees in the mature and overmature classes was not also important as a breeding medium became apparent as a result of these records. Slash of this character was to be found in considerable quantity in the virgin mixed conifer type at elevations above 4,500 feet which were being logged during the summer, 1947. Thus, an opportunity to secure some information on this point was provided. Counts of mature broods were obtained in infested slash from 11 mature and overmature trees varying in age from 201 to 475 years.

The abundance of brood in individual trees as revealed in table 9 shows no clear-cut relationship between host age and production of mature

Table 8.—Phloem Moisture and Ips Broods Produced in Prepared Field Tests (Lopped and Unlopped Trees, Sites I and II)

Tree #	% Moisture at 10-Day Intervals 1	2	3	4	5	Ips Attacks Per Sq. Ft.	Brood Produced Per Sq. Ft.	Brood Produced Per Inch - Egg Gallery
UNLOPPED TREES								
Site II								
1A	163.1	131.7	134.4	181.7	163.2	15	92	1.53
1B	184.8	177.8	165.5	153.2	183.6	8	70	1.00
1C	156.4	153.2	145.9	163.2	163.2	16	70	1.30
1D	163.2	131.7	140.0	170.3	98.9	14	120	1.60
1E	156.4	156.4	152.1	207.7	150.0	9	84	1.40
Average	164.8	150.1	147.7	175.2	151.7	12	87	1.36
Site I								
2A	163.2	181.7	173.9	108.3	138.1	17	35*	.35**
2B	173.9	146.9	222.6	222.6	189.9	11	25*	.25**
2C	222.6	196.3	233.3	222.5	316.7	11	25*	.25**
2D	129.8	173.2	217.5	163.2	189.9	16	10*	.10**
2E	203.0	194.1	170.3	159.7	222.6	10	25*	.25**
Average	178.5	178.4	203.7	175.3	211.4	13	24*	.24**
LOPPED TREES								
Site II								
1F	144.6	163.2	175.2	232.7	248.6	7	43	.73
1G	156.4	146.9	143.9	222.5	217.8	8	-	-
1H	196.2	203.0	188.5	198.5	238.5	6	-	-
1I	153.2	153.2	152.1	212.5	203.0	20	65	.57
1J	173.9	174.3	206.1	239.0	248.6	22	38	.65
Average	159.3	168.1	173.2	221.0	231.4	12	49	.65
Site I								
2F	212.5	173.9	189.9	263.6	239.0	13	20*	.20**
2G	173.9	181.7	171.4	181.7	233.3	17	43*	.43**
2H	212.5	171.4	198.5	233.3	251.0	13	60*	.60**
2I	207.7	185.9	198.5	227.9	233.3	8	-	-
2J	207.7	173.9	207.7	244.8	263.6	10	30*	.30**
Average	202.9	177.3	193.2	230.3	244.0	12	38*	.38**

* Approximate brood per square foot, (based on 36 square-inch samples)

** Approximate brood per inch, (based on uniform gallery length, estimated at 100 inches per square foot of bark area.)

broods in the westside ponderosa pine type. On the basis of averages, it appears that there is somewhat less brood produced in the older trees, but not enough less to be considered an unimportant breeding source. Slash created as a result of logging operations in mature or overmature virgin stands, therefore, appears to be about as important as a breeding source for Ips as the slash in younger age stands. However, it is quite apparent that the hazards against attacks in these higher elevation types are less than at lower elevations, presumably because of less competition for soil moisture.

Table 9.--Comparison of Broods Produced in Tops of Young and Old Trees

Age Group - Years	Top #	Mature Brood Per Sq. Ft.
75-150	1	171
	2	231
	3	139
	4	149
	5	207
	Average	179
200-275	1	102
	2	56
	3	160
	4	200
	5	260
	6	150
	Average	155
275-475	1	25
	2	172
	3	160
	4	158
	5	44
	Average	112

Comparative Breeding in Lopped and Unlopped Slash

In the westside study areas, the most important type of logging slash as a breeding source, as shown by the 1946 [4] investigations, is tops varying

4/ Struble, G. R., 1947. A Study of Factors in the Development of Ips Outbreaks. Progress Report of Sierra Studies - 1946.

in basal diameter from 14 to 24 inches. The largest and most consistent numbers of mature brood are found in tops; without question, it is this material that is first to be considered in practices that will limit or prevent breeding.

One means of limiting breeding in tops is to lop all limbs as soon as the trees are felled. This procedure, now in practice in many areas of government-owned timber, has provided ample opportunity for observations on its effectiveness in reducing Ips populations. Beginning in 1947 the Hugh Ryan timber sale area, for example, was logged with this practice stipulated in the contract. The amount of breeding in the lopped slash was determined by a check of 50 tops in a small basin facing predominantly eastward. A check of 50 unlopped tops in a privately-owned logging area at Barrett Ranch was made for comparison (figure 4). Both areas were checked from one to three months after the slash had been created, thus assuring an opportunity for completion of Ips attacks. A summarization of this data in table 10 reveals quite clearly the effectiveness of this practice in limiting the attack and subsequent breeding by Ips.

Table 10.--Slash Character and Incidence of Attacks in Lopped and Unlopped Tops

Basic Factors Considered	Lopped Tops, (Hugh Ryan)	Unlopped Tops, (Barrett Ranch)
Average basal diameter of tops	17.2 inches	14.1 inches
Average height to four inch top	27.1 feet	26.3 feet
% of total tops successfully attacked by Ips	45	100
% of total tops successfully attacked by D. B.	35	0
% of tops in full sun exposure	17.5	100
% of tops in partial sun	67.5	0
% of tops in full shade	15.00	0
Days between cutting and inspection	30-40	80-90

The most significant facts indicated by this check are: (1) That only 45 percent of the tops in the lopped area were attacked by Ips, compared to an attack of 100 percent in the unlopped tops of the privately-owned area; (2) that these differences appeared to be most strongly affected by high temperatures induced by exposures to the sun, even where the tops were partially shaded by the reserve tree canopy; (3) that only 35 percent of the lopped tops were attacked by D. brevicomis for apparently the same reason; and (4) that 20 percent of the lopped tops were unattacked, and most of them were lying in full exposure to the sun. It is to be noted that all of the unlopped tops in the privately-logged area were lying in full exposure to the sun, but the shade provided by the unlopped limbs fostered an ideal breeding medium in the main boles. Broods were heavy in all successfully attacked slash.

This information clearly demonstrates that lopping is distinctly advantageous in preventing excessive breeding by Ips. Increased temperatures under the bark following lopping appear to be the most important limiting factor, but the moisture factor also may be very important. Immediate removal of limbs from the tops after felling prevents the loss of moisture from the main stem through transpiration by the foliage. Thus, the moisture in the main stem tends to remain there and may even increase through the hydrolysing action of deteriorating tissues after a period. This may be presumed to have a detrimental effect on the production of brood as has been indicated in many of our observations. Hence, it is evident that the lopping of limbs tends to limit broods produced both by temperature increases and moisture increases. Of the two factors, it is believed that temperature is more important, especially in areas where the slash is fully or partially exposed. Under fully shaded situations, the lopped slash is more apt to limit brood production through excessive moisture in the phloem area.

SUMMARY

Studies were continued during 1947 on the biological and host factors involved in outbreaks of the five-spined engraver beetle, Ips confusus Lec., in westside ponderosa pine stands of the southern Sierra sub-region. Previous investigations emphasized the need for further information on seasonal biology, natural control factors, and host factors involved in the breeding environment as a basis for better management of ponderosa pine to control Ips outbreaks. The abundant logging slash of some 30-odd sawmills in western Mariposa and Madera counties offered an ideal opportunity for the continuation of this work intermittently through the fall, winter, and spring periods, and continuously through the summer and early fall.

The most significant points as revealed by these studies are:

1. The winter period (1947-1948) was spent in the mature brood stages, mainly as adults, but also as fully grown larvae and pupae beneath the bark of infested slash and trees. Eggs and small larvae were not found, even though mature adults (many parents) made up a large proportion of the hibernating stages.

2. Four complete generations were produced in 1947, even though the breeding season was early and prolonged. This production is considered normal for the central and southern Sierra latitudes.

3. A consistently high population of adults emerged from spring, summer, and fall slash material, with the greatest number in spring and early summer slash. The average spring and summer emergence from 14 samples involving 42 square feet of bark area was 145 beetles per square foot.

4. Emergence from a small number of trees attacked during the fall amounted to an average of 66 beetles per square foot.

5. Attacks by Ips in living timber appear to be related to a sudden build-up in numbers of adults reared in a given area.

6. The concentration of adults in groups of saplings or larger trees in midsummer appears to be related to an attraction stemming from competition for soil moisture, and not to a feeding requirement. Only very limited breeding occurs under these conditions.

7. Controlled experiments showed that parent adult emergence varied between 20 and 50 percent, depending on the degree of crowding; this takes place regularly 20 days after attacks are initiated. They further revealed that emerged parent adults produced normal-sized broods in re-attacked material.

8. Further data on insect enemies in 1947 again revealed that they were relatively unimportant as an effective control factor.

9. Abundant fungus growth in infested slash seriously affects the development of mature broods, but its presence appears to be related to a phloem condition that will foster its growth.

10. Preliminary field tests on the relation of phloem moisture to mature brood success in lopped and unlopped tree tops were inconclusive, but strongly indicated that this factor is important in determining success or failure. The tests were undertaken in tree growing Sites I and II.

11. Broods developed in slash from mature and overmature trees in westside pine areas were found to be as large as those produced in slash from younger trees.

12. Checks on the incidence of attacks in lopped and in unlopped slash revealed that lopping has a decided influence on attacks made. In 50 trees of each character checked, only 45 percent of the lopped tops were attacked by Ips compared to a 100 percent attack by Ips in the unlopped tops. Differences were attributed to high temperature and moisture conditions beneath the bark of lopped tops.

Figure 1. (Photo #13352).—Emergence cages used in 1947 studies. Special rabbiting of five-ply plywood sections insures against the escape of the most minute insect species. Ample ventilation prevents excessive accumulation of moisture. Each cage (18"x18"x24") accommodates an infested log section having three square feet of bark area. Pint size mason jars provide adequate collection chambers.

Figure 2, (Photo #13354).--Part of about 500 saplings in one group attacked and killed by Ips adults during July, 1947. They are located on the crest of a ridge.

Figure 3, (Photo #13353).--Part of clear cut area at Barrett Ranch. With the limbs of tops providing shade, 100 percent of this slash was very heavily attacked.